Photosynthesis: Dark Reactions

Chapter 8.3

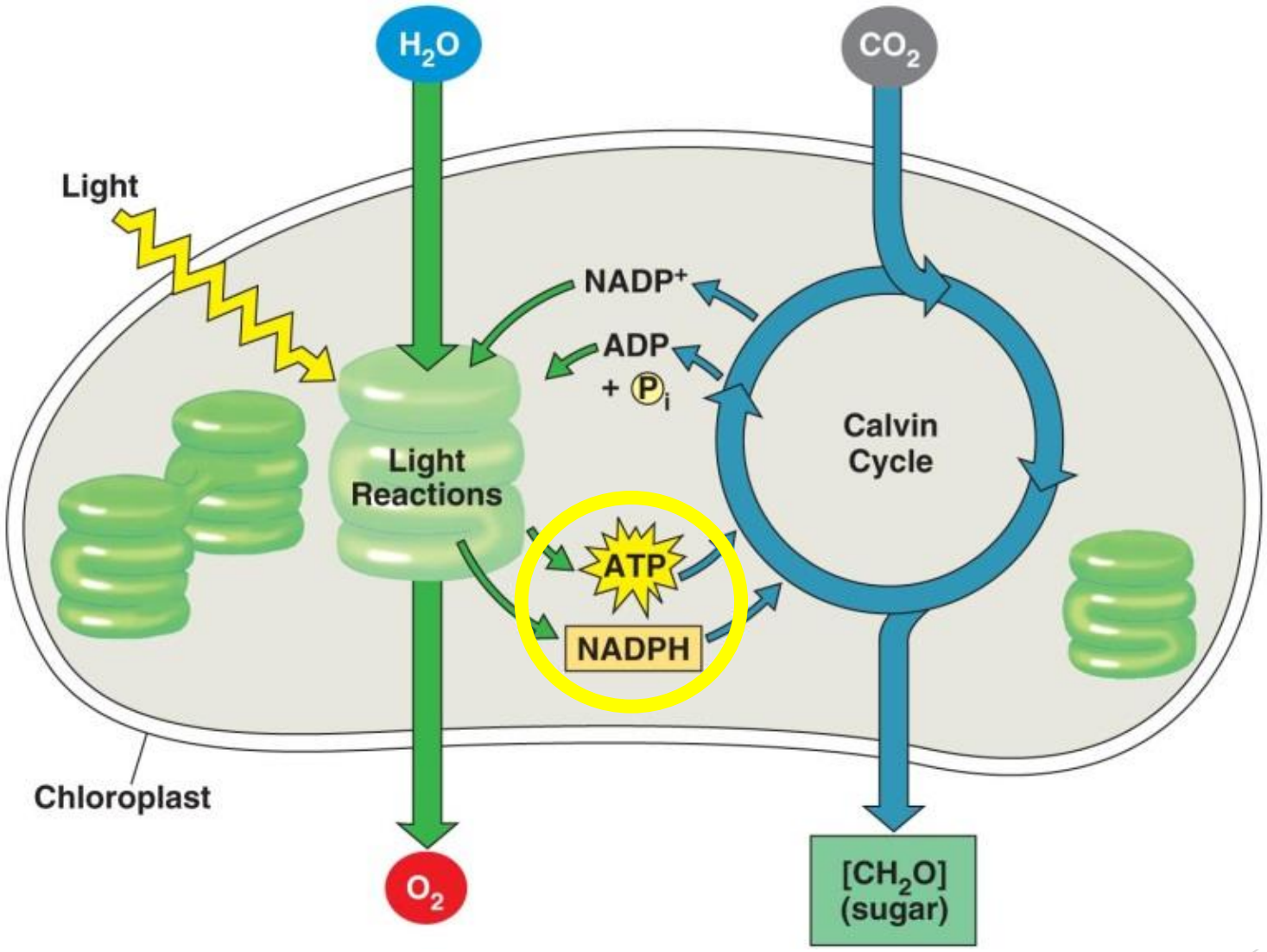
Biol 1A

California State University, Fresno

Learning Goals

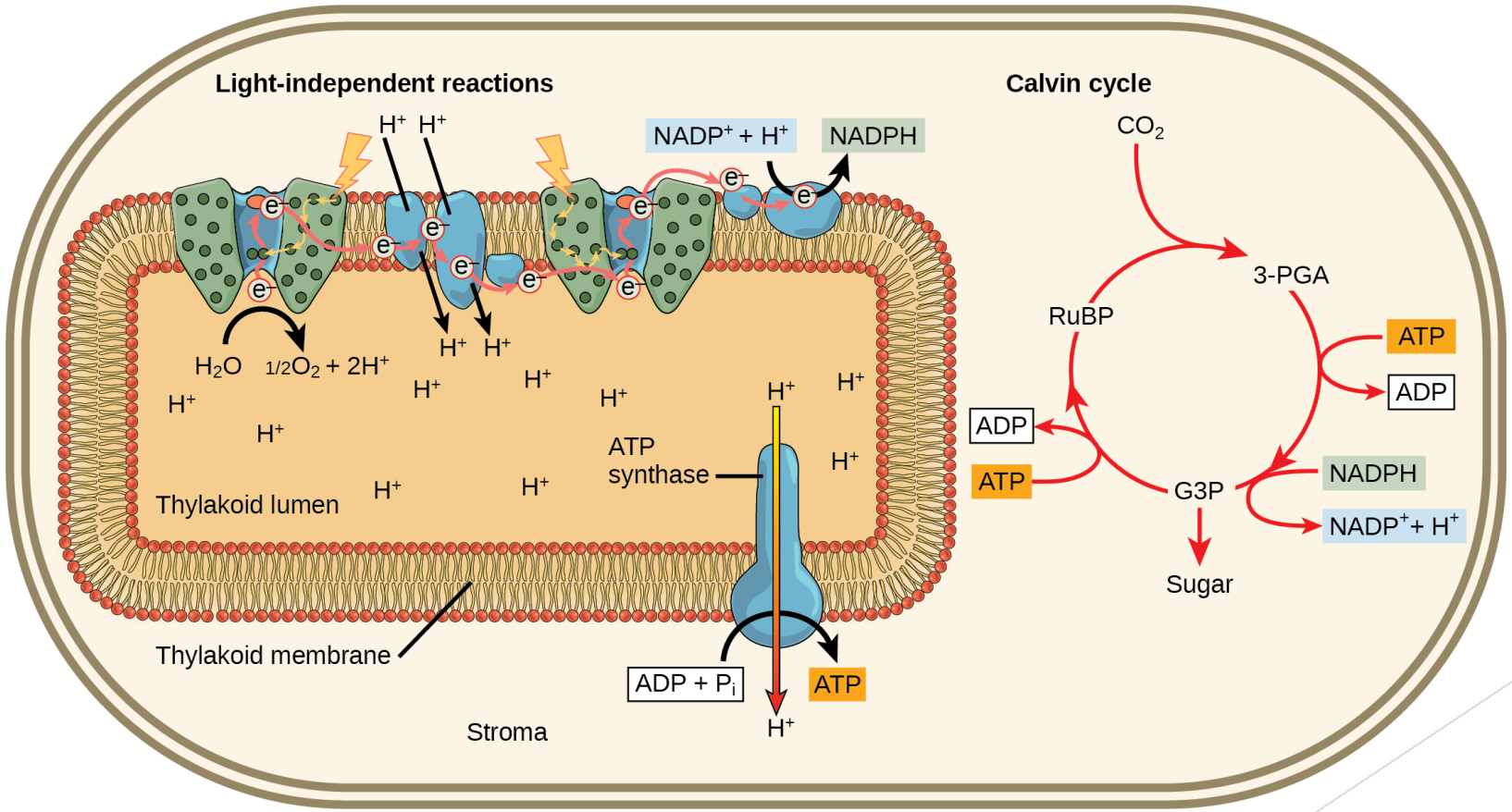
1. Describe the three stages of the Calvin Cycle and how it is related to the light reactions.
2. Understand how plants obtain carbon dioxide and water.
3. Describe how C4 and CAM plants reduce photorespiration and conserve water.

overall reactions of Photosynthesis

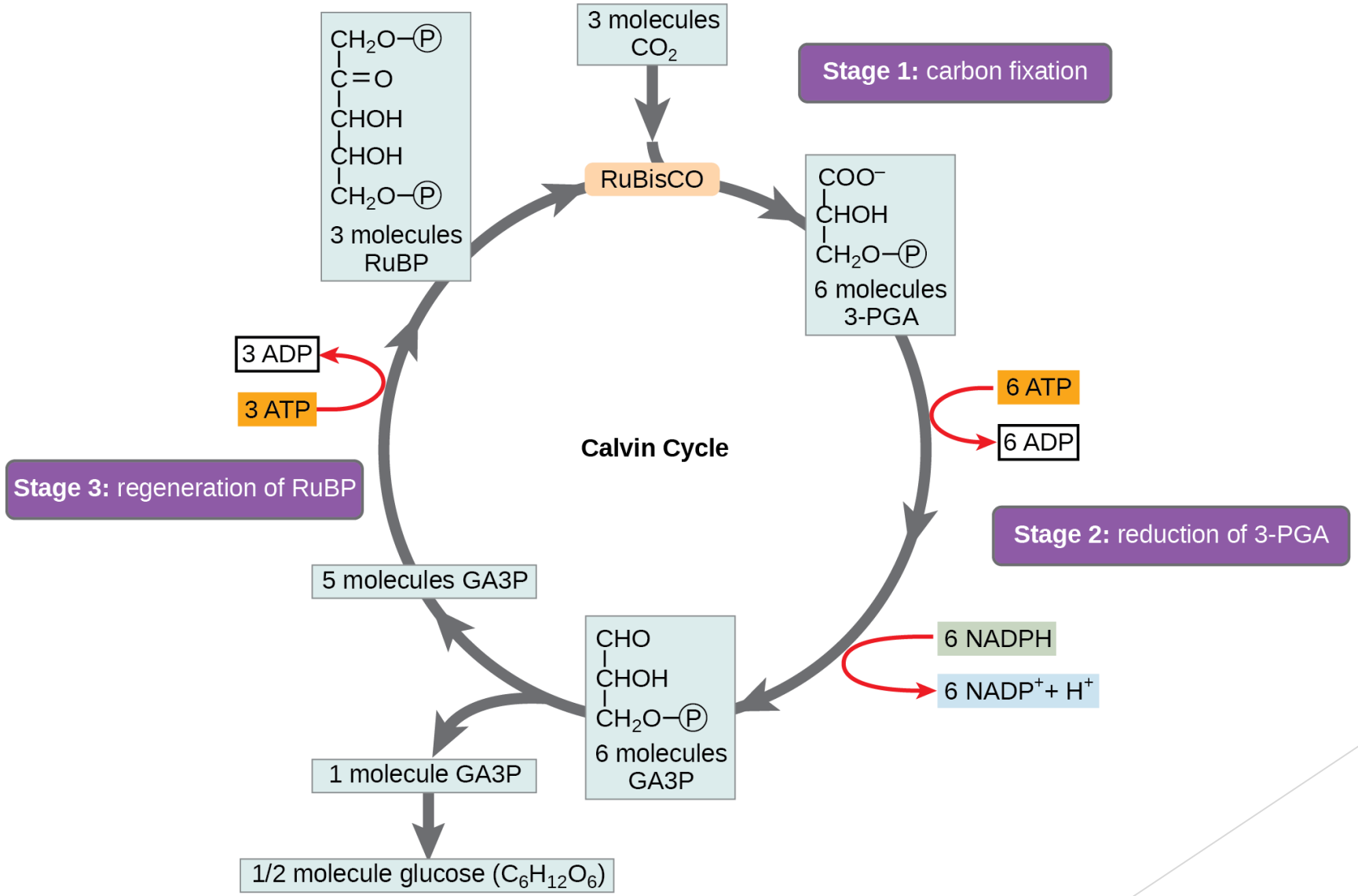


Using Light Energy to Make Organic Molecules

After the energy from the sun is converted into chemical energy and temporarily stored in ATP and NADPH molecules, the cell has the fuel needed to build carbohydrate molecules for long-term energy storage.



The Calvin Cycle



The Calvin Cycle

Phase 1 - Carbon fixation

- CO_2 incorporated into RuBP using **rubisco**
- Reaction product is a six-carbon intermediate that splits into two 3-phosphoglycerate molecules (3PGA)

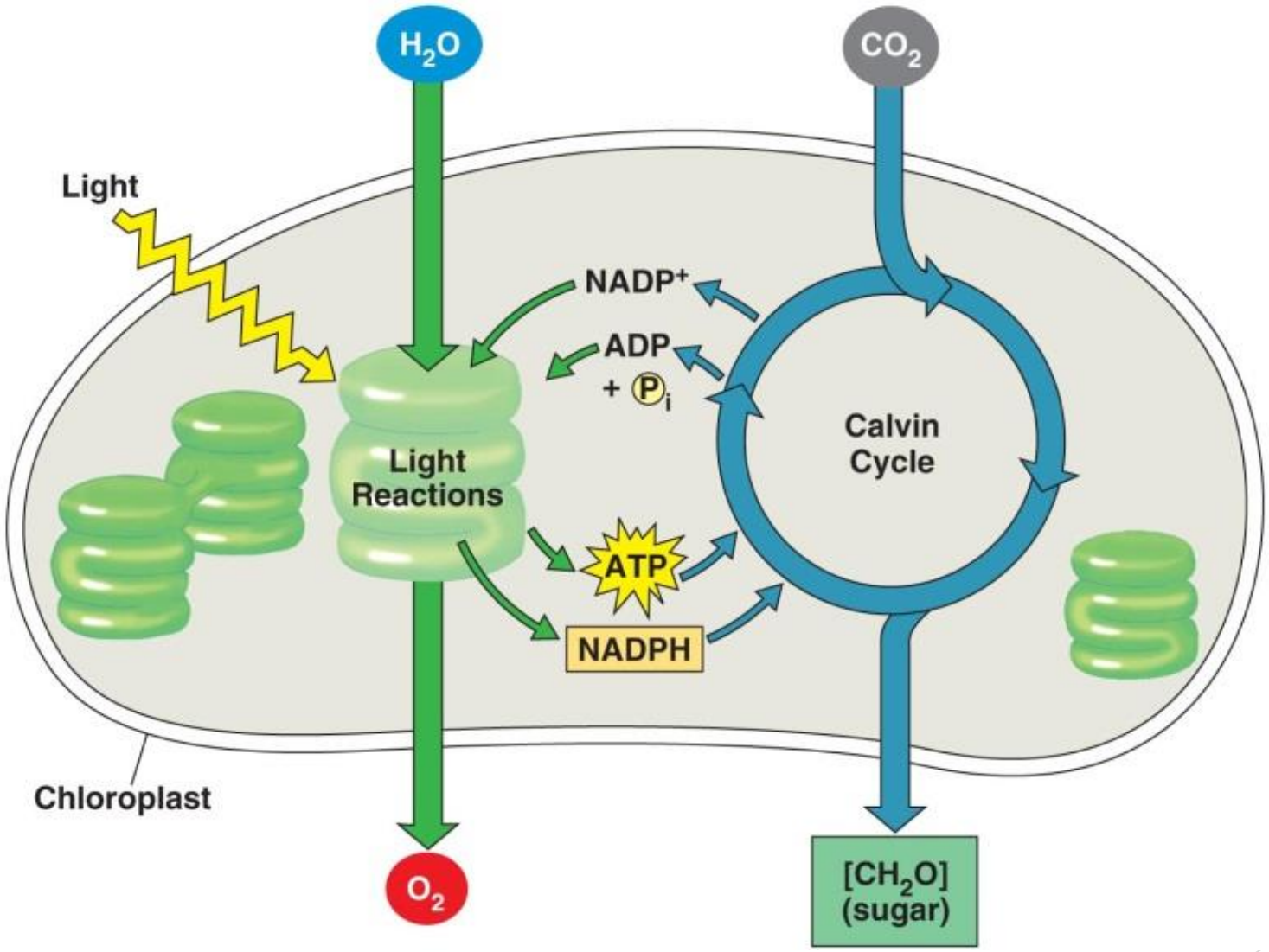
Phase 2 - Reduction and carbohydrate production

- ATP is used to convert 3PG into 1,3-bisphosphoglycerate (1,3-BPG)
- NADPH electrons reduce it to glyceraldehyde-3-phosphate (G3P)
- 3 CO_2 $\rightarrow$ 6 G3P
  - Only 1 G3P molecules used for carbohydrates
  - 5 G3P molecules must be used for regeneration of RuBP

Phase 3 - Regeneration of RuBP

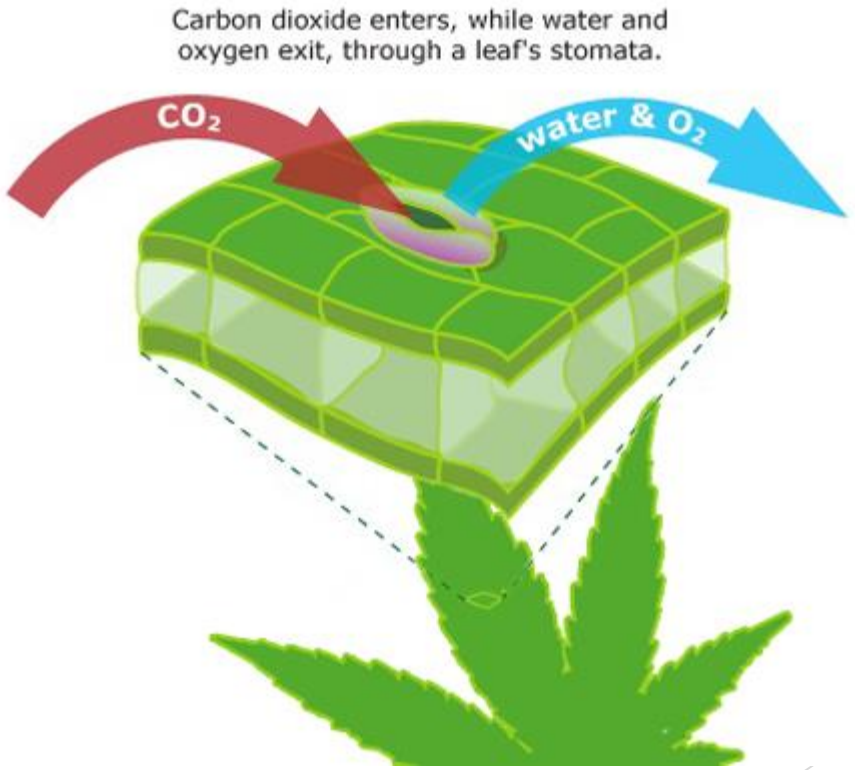
- 5 G3P are converted into 3 RuBP using ATP

overall reactions of Photosynthesis



The Stomata

- On hot, dry days, plants close stomata, which conserves H_2O but also limits photosynthesis.
- The closing of stomata reduces access to CO_2 and causes O_2 to build up.
- These conditions favor an apparently wasteful process called **photorespiration**.
- In **photorespiration**, rubisco adds O_2 instead of CO_2 in the Calvin cycle, producing a two-carbon compound

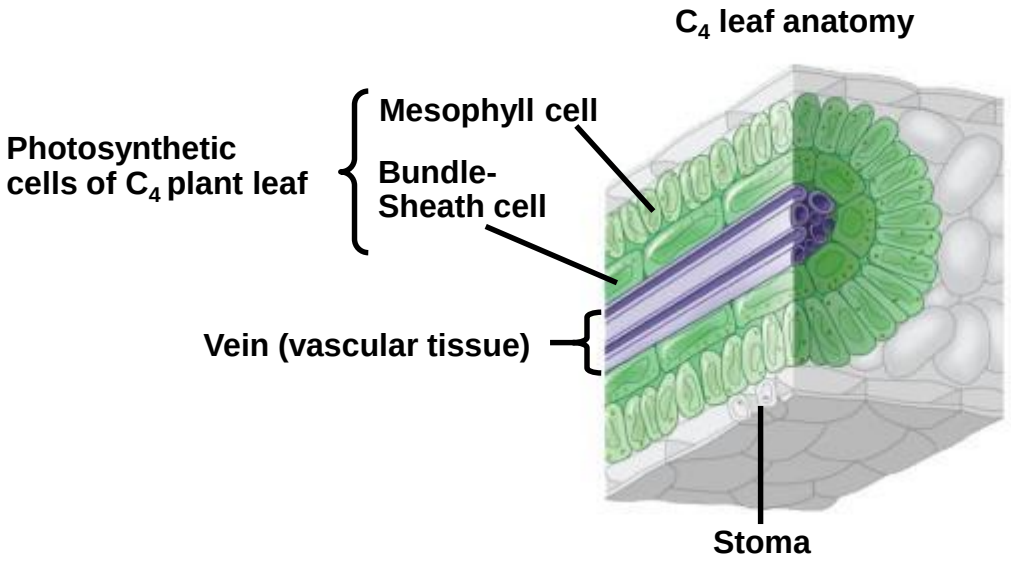


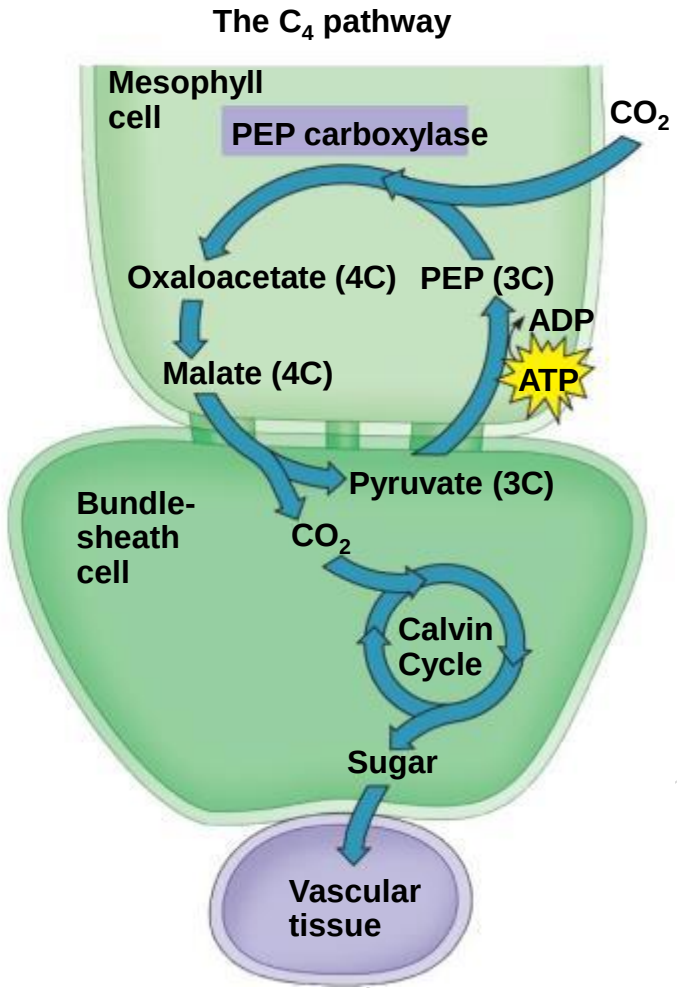
Evolution of Photosynthesis

- Photosynthesis in desert plants has evolved adaptations that conserve water.
- **Crassulacean acid metabolism (CAM) plants:** *temporal* separation of photosynthesis to reduce photorespiration.
- **C_4 plants:** *spatial* separation of photosynthesis to reduce photorespiration.

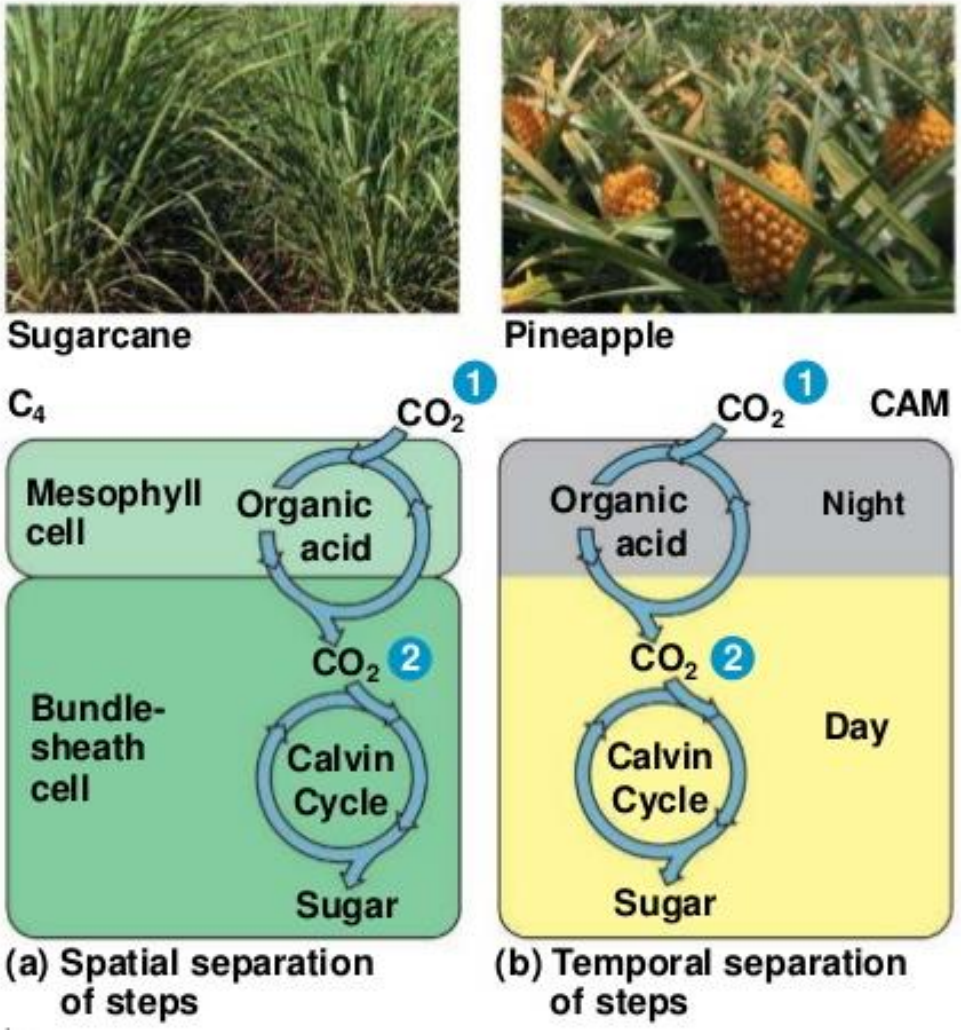
C_4 Plants: spatial separation

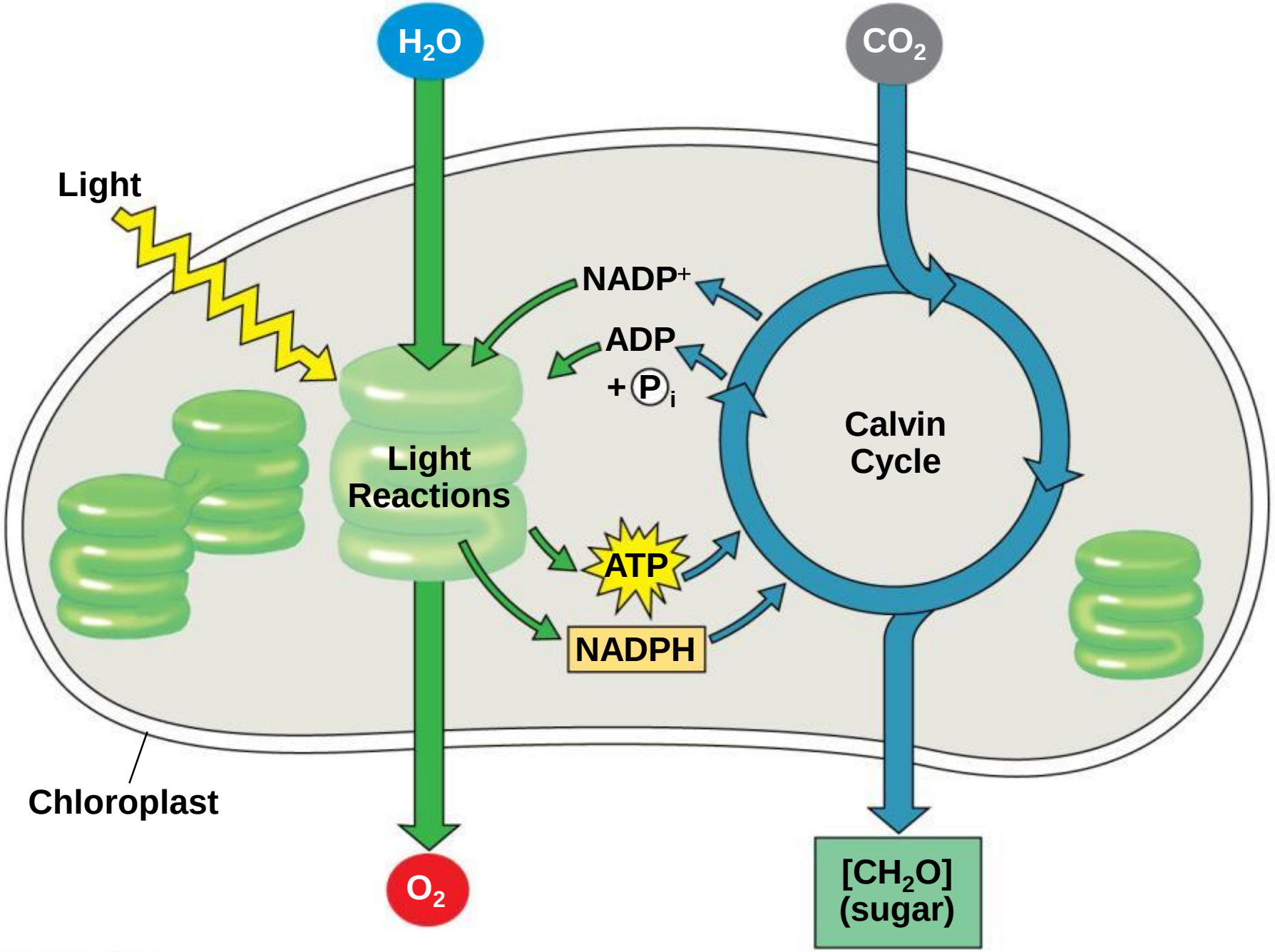
- **C_4 plants (sugarcane, corn)** minimize the cost of photorespiration by incorporating CO_2 into four-carbon compounds in **mesophyll cells**
- This step requires the enzyme **PEP carboxylase**





CAM Plants: temporal separation




H_2O
CO_2
Light
$NADP^+$
ADP
$+ P_i$
Calvin Cycle
Light Reactions
ATP
NADPH
Chloroplast
O_2
$[CH_2O]$ (sugar)

Take Home

1. Three carbon dioxide molecules are fixed (added to RuBP) into the Calvin cycle by the enzyme Rubisco to form 3PGA, a three carbon molecule.
2. Energy from ATP and electrons from NADPH are used to in the reduction phase to produce G3P, a three carbon sugar. One molecule of G3P leaves the cycle and can be used to build many different organic molecules. Two turns of the Calvin cycle would be required to make glucose.
3. The last stage of the Calvin cycle regenerates RuBP using ATP to restart the cycle.
4. Plants must open their stomata to let in CO_2 for photosynthesis and let oxygen out. However, open stomata also wastes water as it is evaporated.
5. Photorespiration occurs when oxygen, a byproduct of the light reactions, enters the Calvin Cycle instead of carbon dioxide. This wastes energy and materials.
6. C4 plants limit photorespiration by spatially separating the carbon fixation from the light reactions.
7. CAM plants temporally separate the two processes, fixing carbon dioxide at night.